THESIS

JOB PROGRAMMES
AND
COST SCHEDULES

N.B.Spong.

C O N T E N T S

Contents	Page Number

INTRODUCTION

The examination of records of performance and of cost kept during the progress of construction jobs, shows that the greatest cost item is labor, with plant costs running a close seoond. The trend to more complete mechanization will mean that these positions will be reversed.

With the realisation of the importance of the plant comes the knowledge that where possible the plant should be worked continuously, except for definite periods of maintenance and overhaul. Plant standing idle is invested money not earning a dividend, whether the idleness is due to bad planning or breakdown.

Programming then consists essentially of choosing the best plant for the job, and arranging things so that the plant can work at its maximum efficiency, both in output and unit cost. The method of choosing the plant is based largely on experience, supplimented by performance date. This performance data can be derived from properly set up and honestly kept records.

The cost structure is best understood by referring to figures shown on page, which shows that the rate of expenditure will be very high early in the job, but will taper off as the job progresses. The rate of progress payments is fairly constant, so that it is at some stage near the middle, or later in the construction period, that the job starts to show some returns for the money invested. The planer's problem is to arrange the finances to cover this period of insolvency. This can be done by issuing bonds, bank loan, or an agreement with a more prosperous construction firm.

As with the job programming, the cost can be decided ahead, but unless close watch is kept on the progress of both of these items, the situation may get out of hand. Control can be exercised by frequent estimation of the state of the job and the costs. The difficulty or ease of this calculation is a reflection of the efficiency of the recording system, and the trouble taken in the recording.

GENERAL CONSIDERATIONS

THE FIRST PROGRAMMING.

Usually, when a project is proposed, the stages of construction, or division in to sections, is forced upon the constructing authority by forces outside his control, e.g., in the case of a dam, it is necessary to take in to account the likelihood of seasonal flooding, and the building and dismantling of bulkheads or coffer dams, and the work behind them must be scheduled accordingly.

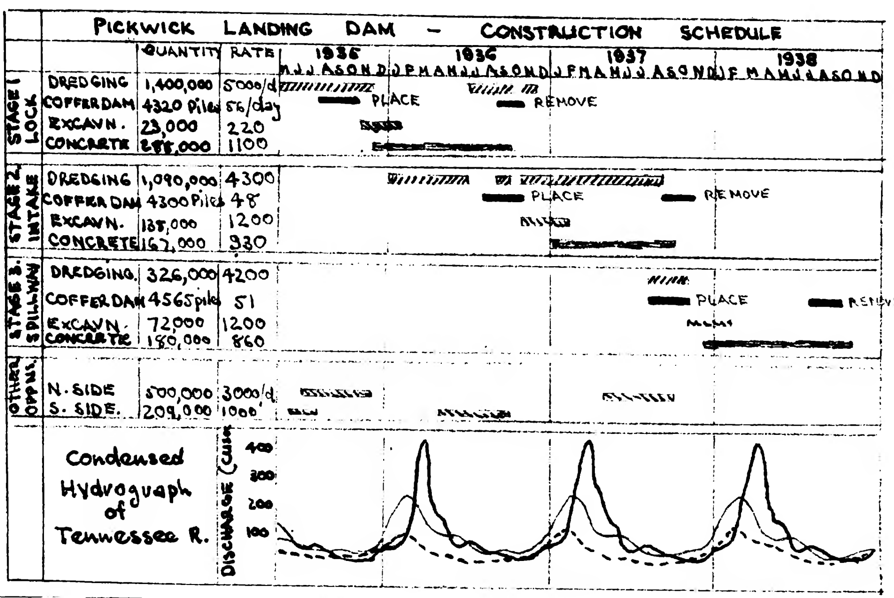


FIG. Backbone Schedule for Pickwick Landing Dam.
Note breaking of job in to three stages to fit in with the river regeme as represented by the Hydrograph.

In the construction of an aerodrome, it is Governmental policy to have one runway working as soon as practicable, for possible emergency use, both civil and military. In power station construction, since the construction period of a thermal station of four units is usually from eight to ten years, the sooner the first unit is producing the better. The rates of depreciation apply here, since the time the unit is waiting to go in to operation it is rusting, risking injury, or becoming antiquated as new, more efficient methods are being developed.

PRELIMINARY ESTIMATING.

Once these points have been decided the project resolves itself in to a question of basic engineering processes, e.g., a certainqunatity of land to be cleared, a certain quantity of excavation to be carried out, a certain quantity of fill to be placed and compacted, each to be done within certain time limits. At this stage it is possible to carry out a preliminary estimate of cost, using "average unit costs", which will tell the contractor

whether it is possible for him to bid for the contract, and will tell a Government Department wheher it can fit the cost of the project in to its budget, whether it would be more economical to let contracts for certain parts, the lot, or have it all done by day labor.

It is also possible at this stage to see where the major items of cost will be, and by altering design to affect economies and bring the cost down to a point where it may be included in the allocation of funds, which it otherwise might not be.

The "average unit cost", which, it must be understood, is not the lowest possible cost, is the average cost of carrying out the same amount of work of a similar nature. The accuracy will depend on the information available relating to the job, and also the records of past jobs. Providing accurate records have been kept, some idea of the probable cost can be obtained, but due to the difficult nature of, and uncertain factors in some operations, the risk involved may entitle the contractor to a greater profit; or else the constructing authority may be emtitled to some degree of latitude so far as costs of difficult or unusual operations are concerned.

PRELIMINARY PLANNING.

At this point the methods of operations, and the plant can be tentatively decided, although the best possible combination of plant may not be available, or else use must be made of standard equipment possessed by the Department, or again it may be that several combinations of plant seem to have equal attractions. Then by process of elimination, on scores of replacement parts, standardisation, the possibility of using bought equipment on other jobs as compared with hiring units for the period required, one scheme is finally adopted.

DETAILED ESTIMATES.

It may even be necessary to carry out a detailed estimate for each possible scheme, to decide which to adopt. Even if not necessary for this purpose, a detailed estimate should be made at this juncture. The detailed estimate should be of standard form such that ~~can~~ it can be used for future estimates. Even though large projects differ greatly, the component parts of the items in to which it is broken remain the same, i.e., excavation can be standardised as shown.

The same is true with all other direct items of cost. For indirect items, or on cost it is usual Governmental proceedure to estimate them as separate items of cost. This is for accuracy and also to "purify" the estimate. Usuall, a contractor works out "on cost" as a flat rate, and percentage of the total direct cost and

it is distributed amongst the direct cost items pro rata.

OPERATION	METHOD OF EXECUTION	TYPE OF MATERIAL	QUANTITY SOLID MEASURE	STANDARD UNIT RATE	COST
1/ PRELIMINARY LOOSENING	1/ BY D8 TRACTOR & POWER CONTROLLED RIPPER	HARD EARTH	10,000 CU.YD	4 d.	£167
		MED. HARD SHALE	38,000	8d.	£1,267
	2. DRILLING & BLASTING. A COMPRESSOR, 2 JACK-HAMMERS + TIPPED DRILLS	HARD SHALE	40,000	6/-	£12,000
		HARD GRANITE	10,000	14/-	£7,000

FIG. TYPICAL ITEM OF DETAILED ESTIMATES

OTHER ESTIMATES.

This is usually only the first of three detailed estimates. The second is carried out as soon as the job has been in progress long enough to fix the unit costs, and is a check on the first estimate. The third estimate is carried out as the job draws to a close, to estimate the final cost, but this is more of a collection of costs than an estimate.

JOB PROGRAMMING.

The foregoing should have been carried out before the work is finally authorised, or else before contracts are let, Once the job has been signed up however, and money has been allocated to it, the actual programming can begin.

In essence, programming consists of setting out a detailed plan of operations which will be rigidly adhered to as being the most desirable rate of performing the particular item of work. It will take in to account order of works, availability of plant, and allowance for maintenance, available labor and material, and available funds.

Obviously clearing must start before excavation, and excavation before pouring foundations, but due to the dictates of an overall time schedule ways have to be found of arranging the clearing so that excavation can be commenced before clearing has finished, and foundations started before excavation finished. Again, however, due to the availability of excavating plant, but non-availability of concreting plant, it may be necessary to perform the first two, as above, with the time lapse before the commencement of the third. In this case the cost of resultant timbering of excavations would have to be cheaper than the cost ofhiring the necessary extra concrete plant for a short period.

Thus programming is a form of design, and as such

is a series of compromises in order to get the best over-all effect. It should be accepted as being the best method, and every effort made to follow it, and to attain, or better, the figures set.

PROGRAMMING OF PLANT.

CHOICE OF PLANT

The opportunities for using special equipment are usually confined to the very large Works, and so for most construction projects, combinations of standard equipment are used. This has the added advantage of availability of replacement parts, simplicity of maintenance, interchangeability of plant and operators, and the over all consideration that brakdown of one unit does not cripple the production line.

The choice of which items of equipment and their number is often a great problem when programming plant. To help overcome some of these difficulties, manufacturers generally issue their plant performance information in terms of "average yardage moved". taking in to account losses in time and efficiency.

	TRACTOR DRAW-BAR H.P.							
	25 - 30 H.P.		35 - 40 H.P.		60 - 65 H.P.		100 - 120 H.P.	
LENGTH OF HAUL	FIRM DIRT	LOOSE DIRT.	F	L	F	L	F	L
50 ft.	28	60	35	60	85	125	115	180
100	22	30	24	36	50	80	70	115
150	15	22	17	25	35	60	50	85
200			13	21	30	45	40	65
250					23	35	33	50
300					15	25	25	36
350							20	30
400							15	25

Table Performance Data of "Britstand" Bulldozers.

STRUCT CAPACITY (CU. YDS) HEAPED CAPACITY / LENGTH OF HAUL ONE WAY	4·2 CU.YDS. HYDRAULIC 5·0 CU.YD	4·7 CABLE 6·0	7·9 CABLE 9·0	8·6 CABLE 10·0	11·0 CABLE 14·0	12·5 CABLE 16·0
200'	54	62	82	100	123	146
300	46	52	70	85	105	125
400	39	45	61	74	91	108
500	35	40	53	65	80	95
600	31	35	47	57	70	83
700	27	31	41	50	62	73
800	24	27	37	45	55	65
900	22	25	33	41	50	60
1000	20	23	31	37	46	55
1200			26	32	39	46
1500					34	40
2000					26	31

Table Performance Data of "Britstand" Scraper - Tractor Combination

The following "pie diagram" which was drawn from the results of Power Shovel operations, by the Highway Research Board, gives the actual average working time as 37%, with other losses as shown. This is possibly a little misleading, as the job these results were taken from was adversely affected by wet weather. A drag line would not have been affected so seriously, while trucks and rubber tyred scrapers would have been almost useless.

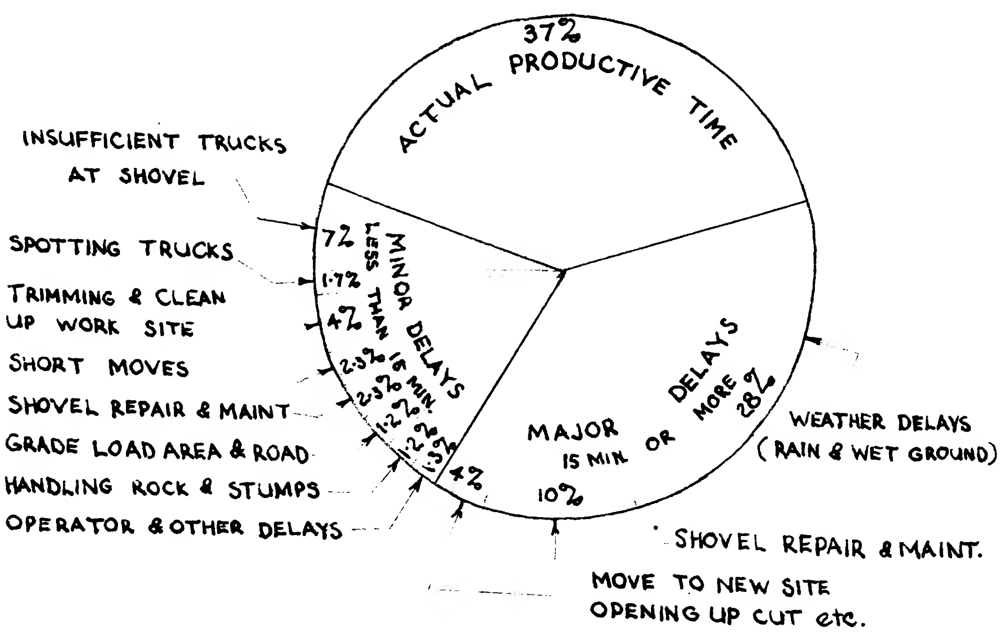


Fig. Power Shovel Productive Time.

Average of 16 power shovels on 10 highway jobs
Data from Highway Research Board, 1947-1949.

Thus we see that although some, or most, of the losses can be avoided or minimised, e.g., waiting time can be cut down by use of more trucks, turns can be cut by greater use of reverse gears, opening up of cut can be speeded by use of assisting equipment, and shovel repair time by adequately planned maintenance; there is a maximum efficiency which can be expected. The figure of a "45 minute hour" is a frequently adopted, and not unreasonable one. The manufacturers performance figures work on this approximation, and so for average conditions the plant required can be reckoned straight from their tables.

Supposing, however, in the construction of an air port, one of the major items was the importing of borrow material a distance of 1.5 miles. To speed construction the road to the borrow area was extended, thus allowing the use of rubber tyred Tournapull units and scrapers at a high rate of speed. This would <u>not</u> be an average case, and would be better tackled by breaking the problem in to its components as shown.

Material = 70,000 cubic yards sub-grade borrow.
Lead = 1.5 miles, average speed = 14.5 M.P.H.
Allowing three minutes per trip for loading and unloading the cycle time becomes

$$\frac{1.5 \times 2 \times 60}{14.5} = 12.4 \text{ minutes}$$

12.4. minutes + 3 minutes = 15.4 minutes per cycle

Supposing that 15 cu. yds. (heaped) scrapers were used, needing a tractor to assist when loading. Then allowance for a 45 minute hour, and a consolidation factor of 0.8 then the rate becomes

$$\frac{15 \times 0.8 \times 60 \times .75}{15.4} = 37 \text{ cu. yards per hour}$$

$$\text{total time taken} = \frac{70,000}{37} = 1860 \text{ hours}$$

This is actually in "scraper hours", and the time taken to perform the job, and the plant available, have to be balanced for best over all effect.

The total time, 1860 hours is a considerable amount, when the reasonably high rate of speed is considered. Were this speed to be reduced to a more average speed of 10 M.P.H. the construction time would be 2380 hours. Thus it would possibly be worth while maintaining the extension of the road from the borrow area, in order to ensure a high rate of speed and lowercosts.

The requirements for the individual units can be calculated as shown, but the best combination to be used may still have to be decided. This can be done by conducting a form of field test, providing the records are accurately kept,and the work done by equipment is comparable.

Supposing it was planned to use one of two different size scrapers, and one of two different make bulldozers, for the Air Port mentioned, in the process of whose construction the extension of the road to the borrow material was required. Then it would be possible to buy, ot hire, two scrapers and two bulldozers of each variety, and by working them in different combinations, e.g.,

1. Bulldozer A Scraper B
2. Bulldozer A, and 2 Scrapers B
3. Bulldozer A, Scraper B
   extra bulldozer A assisting loading
4. Bulldozer A, Scraper C. - etc., to arrive

at the best combination for the main job. This would also allow the operators to become familiar with the operation of the machine and to iron out any difficulties before the main job started.

Where it is not possible to conduct such tests before hand, it may be possible by astute judgement to arrange the plant and order the early keeping of records. The best arrangement may then be decided, and an early indication given of the possibility of doing the job according to programme.

Records from past jobs of a similar nature can be used, e.g., the quantity can be arrived at from records on the Progress Chart at a similar stage of the work, the equipment in use during that time from the Equipment Use Schedule, the cost from the Progressive Cost Schedule, and from the Individual Record Cards of the items of plant concerned. The use of such recorded data is shown in following sections:-

SCHEDULE EQUIPMENT USE

Once the detailed programme has been set, and the choice of plant made, it is only one step further to forecast the strength of the different plant items on a weekly basis. This can be done as shown in the following table

EQUIPMENT SCHEDULE

	1935												1936														
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
AUTOMOTIVE																											
TRUCKS - LIGHT	3	3	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1
- HEAVY	2	2	2	4	6	6	6	6	6	6	6	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2
TRACTORS	12	12	12	14	14	16	18	18	18	18	18	18	16	16	12	12	12	12	12	12	12	12	12	10	10	8	6
EXCAVN. EQPT.																											
DRILLS - WAGGON	1	1	1	6	9	10	10	10	3	3	3	3	10	10	10	3	3	3	10	10	10	6	6	6	6	3	3
- JACKHAMMER	3	3	3	11	19	19	19	19	10	10	10	10	19	19	19	10	10	10	19	19	19	10	8	8	4	4	4
COMPRESSORS - PORTABLE	1	1	1	3	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3	3	3	3
- STATIONARY			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

From the section dealing with Plant Cost, we see the importance of replacement parts and cost incurred while the plant is out of action. The need for regular overhaul becomes obvious as is the use of an Overhaul Schedule, thus to maintain strength of the plant as forecast it may be necessary to replace certain items, or add to the plant's strength from time to time. The plant strength can be gauged at any time by referring to the Weekly Equipment Use Schedule, which shows plant in use, plant idle, and plant under repair.

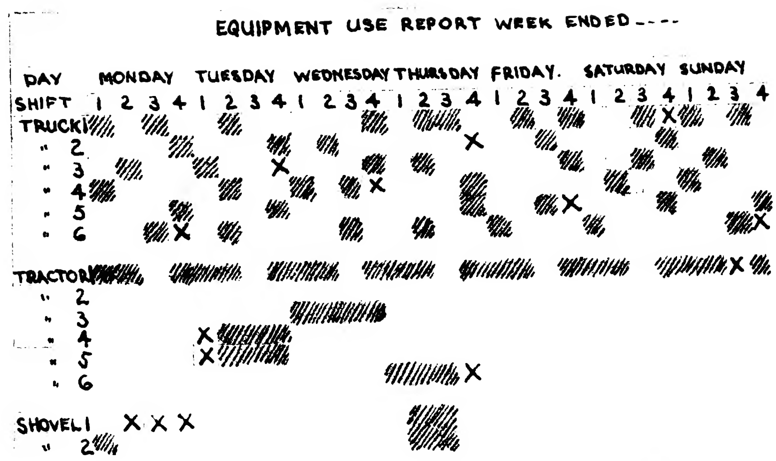


FIG. Weekly Equipment Use Record.
Shows which machines are working, idle or under repair.

RECORDING OF PROGRAMME

Once the job has reached the stage of decision that "a backbone schedule" has been reached, the detailed programming may begin. This is, in essence, breaking the job down to a total of cubic yards and squares and fixing a rate and an overall time. Allowing for loss of efficiency, at start and finish, and allowing for overhaul and repairs, day to day totals, or targets can be set. All the component programmes should then be gathered and allowing for such changes as may be necessary for balance, an overall programme can be fixed. If the job has been properly forecast, contingencies and delays allowed for, the job of construction becomes an effort to maintain the rates of production set. Keeping a close record of day to day production, and recording it against the programme, will give a measure of control, and enable steps to be taken to lift production should it stray below the target figures. The best way of visualising the position is by the use of charts or diagrams.

PROGRAMME CHART

Supposing that the extension of the road to the borrow area mentioned previously, reduced to bare essentials, consists of:-

(a) Earth works 5,000 cubic yards
(b) Formation 10,000 cubic yards
(c) Paving 3,000 cubic yards

The whole job to be finished in eight weeks, to enable the early commencement of the aerodrome, thus taking advantage of available plant.

The programme provided for 1,000 cubic yards of earth works to be carried out in the first week, increasing to 2,000 cubic yards a week for the following two weeks. The formation was to start one week after the commencement of the earth work, completing 1500 cubic yards in the first week, 2,000 cubic yards in the second, 2,500 cubic yards in the third and fourth week, and 1500 in the fifth week.

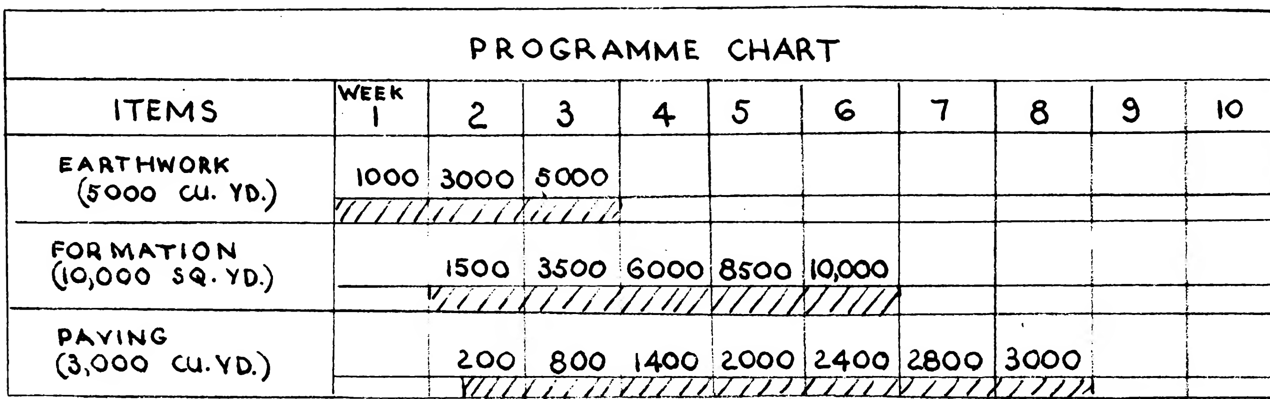


FIG. Programme Chart.
This chart shows target figures set for each item each week

Two days after starting the form tion, the paving was due to commence at the rate of 200 cubic yards for the firstweek, 600 cubic yards each of three weeks, and 200 cubic yards in the eighth week of the job. This fully represented by the chart as shown, with the progressive totals as numbered. However, in the following charts we see the progress recorded.

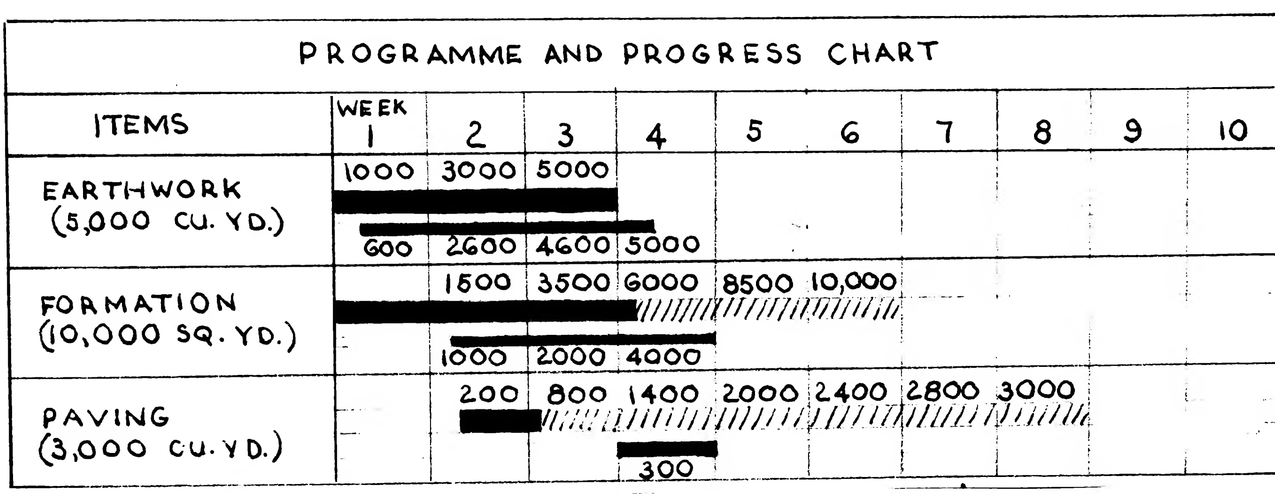


FIG. Programme and Progress Chart at end of 4th week.
This shows that earth work was completed two days late, that 4000 square yards of formation had been completed one week late, and that paving was almost two weeks behind schedule.

PROGRESS CHARTS

The progress Charts show that the job started two days late, but that earth work output was approximately as scheduled; this item being completed one day late. Formation started one day late and was slower than scheduled for the first two weeks, after which it improved, but not sufficiently, and it finished one week late. Paving started more than one week late, and progress was slow in the first week. An improvement occurred in the next two weeks, and output was greater than the planned rate; but as a falling off occurred, the job was not finished until half a week after the target date.

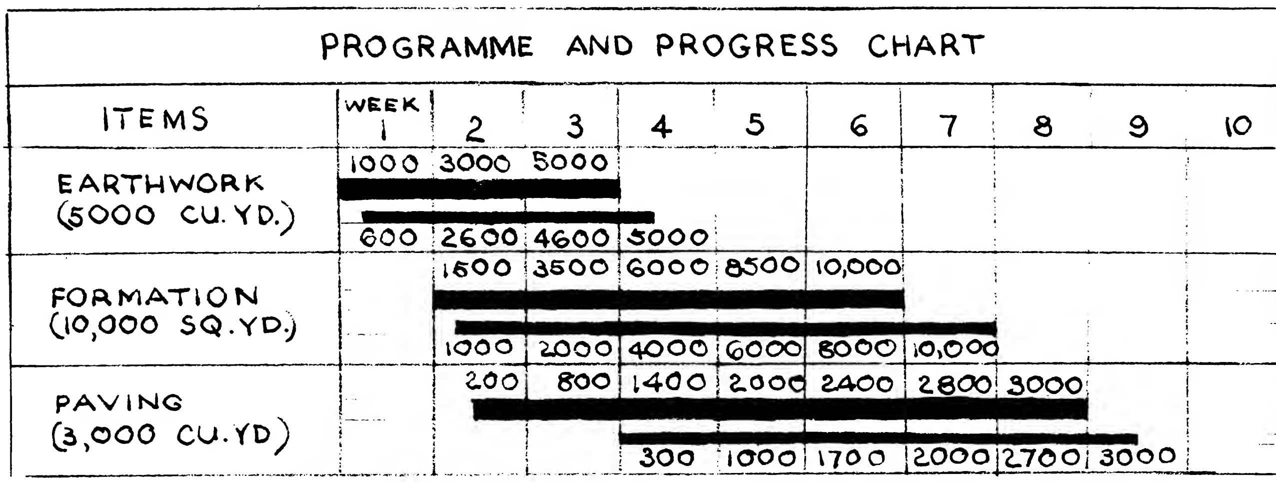


FIG. Program and Progress Chart at completion of Work. This shows that formation finished one week late, and paving three days late.

The same principle can be applied in the progressing of major works, the degree of detail varying as the requirements, e.g., The Summary Sheet, which is made out every month, and accompanies the Expenditure Account for the Department of Works' Aerodrome Projects.

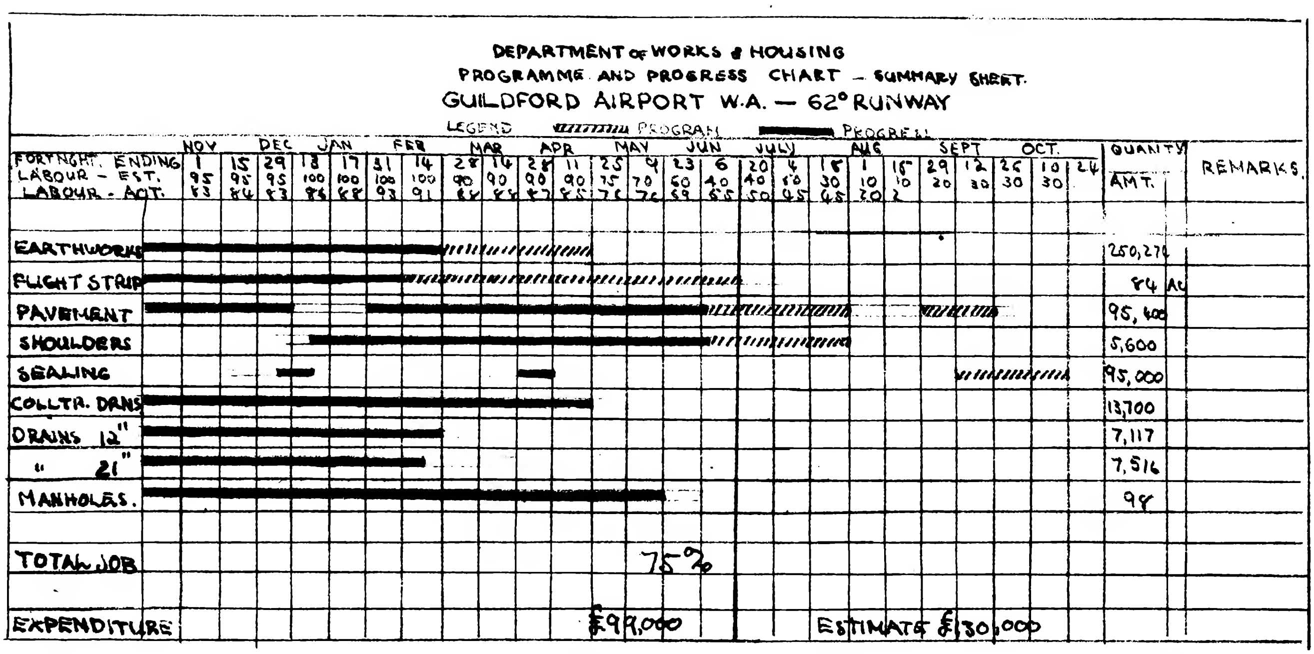


FIG. Summary Sheet as used by Department of Works' for their Aerodrome Projects.

As can be seen, these are the major divisions of the job and the progress is shown in simplest form. Should the Director of Works be dissatisfied with any particular aspect, the Detail Sheet can be called for. This gives a wealth of information, and not only shows Programme and Progress, but shows more plainly how progress compares with forecast from the time consideration.

FIG. Detail Sheet as used by Department of Works' on their Aerodrome Projects.

SPECIAL CHARTS

If it were necessary to keep a particularly close watch on the progress of a particular item or set of items, a form of Double Ordinate Chart should be used. The example shown represents the road referred to earlier, and although useful for simple jobs with a small number of items, soon becomes unweildly; and for larger number of items The Horizontal Bar Chart is preferable.

SUMMARY

Thus the key to recording progress is:-

(1) Simplicity, i.e., keep the main items only on the main chart and use secondary charts for further breakdown and closer check on detail.

(2) To be of any use at all, the charts should be marked up honestly and regularly, say every month, or when the Periodical Expenditure Reports are being made out.

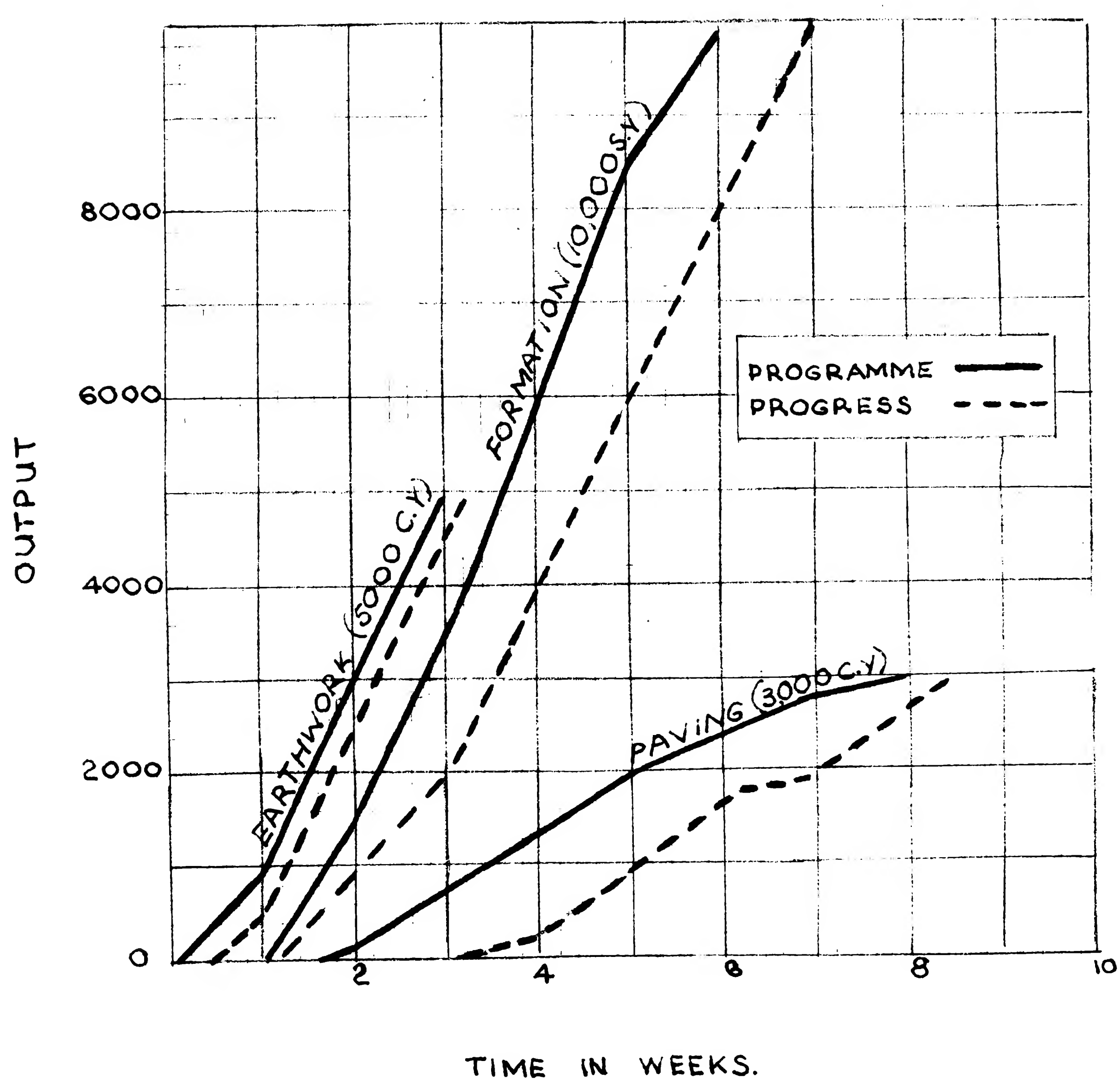


FIG. Special Programme & Progress Chart.
This is used whre it is desired to keep a close watch on performance. Although useful for jobs of a few items only, rapidly becomes unweildly for jobs with larger numbers of items.

USE OF CHARTS

Having gone to the trouble of making out, and keeping progressed charts, they should be used in two ways;

(a) They should guide where remedial measures are necessary to prevent the job falling behind with the resultant financial loss, even if it involves spending at an uneconomical rate for a short time to get back to schedule.

(b) They should be kept as records and referred to when programming future jobs to avoid setting impossible or wasteful targets.

C O S T S

As with the fixing of the best method of performing the job, by breaking it down to its component operations, so the best way to attack the question of costs is to break it down to its components;

(1) Direct cost comprising

(a) Labor Cost
(b) Raw Material Cost
(c) Plant Cost
(d) Contingencies

(2) Indirect or On-Cost, which will depend on the nature and size of the job.

Of these, the greatest cost is usually labor, but the most important is Plant Cost, since this is the most variable cost, and therefore, the item which is most likely to cause the difference between profit and loss for the whole job.

DIRECT COST

LABOR

As previously stated, the labor cost is usually the highest, and this can be easily understood if we imagine a project employing 250 men for two years at £15 per week. The cost will then be

£15 X 2 X 50 X 250 = £375,000

When we learn that Power Stations, whose average total installed cost is approximately £12,000,000, employ in the form of Contractors labor 750 to 1000 men for four years and upwards, we can see that labor is a very expensive item. We can also see that if it is possible to cut down on this particular cost by planning ahead, then it will be well worth while.

The best method of programming the labor force is under the various trades or employment headings. These individual programmes are remarkably constant throughout the job, even though the progressive total varies greatly. The variation is from a minimum at start and finish, to a maximum during the period ofmaximum construction. This uniformity is all the more surprising when we remember that the practice was once to hire a gang for a particular job, and to fire it immediately the job was finished.

The increased use of plant has meant that the operators are usually employed in that capacity for the full period of thejob. Even the manual labourers, which are required for such operations as trimming excavations, loading and stacking materials,cleaning and oiling forms, can have some measure of continuity of employment,by arranging jobs for the periods of slackness.

Such jobs are present on all construction projects and are, e.g., diggng of drainage trenches, cleaning of pits and sumps, relocation of telephone and power lines, dismantling old plant, and general camp maintenance.

A simple and effective record of the labor force can be kept by giving each man a number for reference in the Foreman's Daily Report, and the weekly pay sheet.

From these records a graph of the labor force can be drawn, and from it, and the current wage rates, accumulative cost diagram can be drawn.

Similarly, when we have programmed for certain work to be done, between certain time limits, then by referring to past records of equivalent jobs, in similar periods, we can programme the labor and thus the cost of the labor.

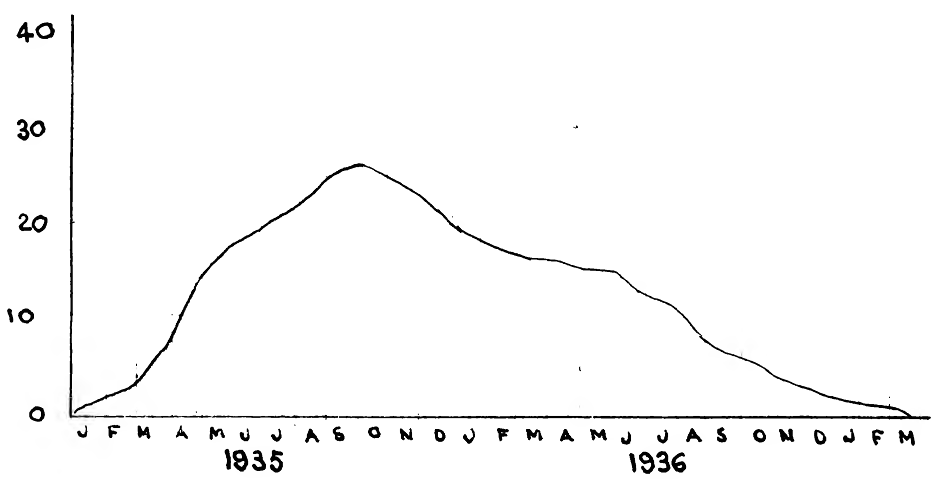


FIG. 12 EMPLOYMENT SCHEDULE FOR ONE TRADE

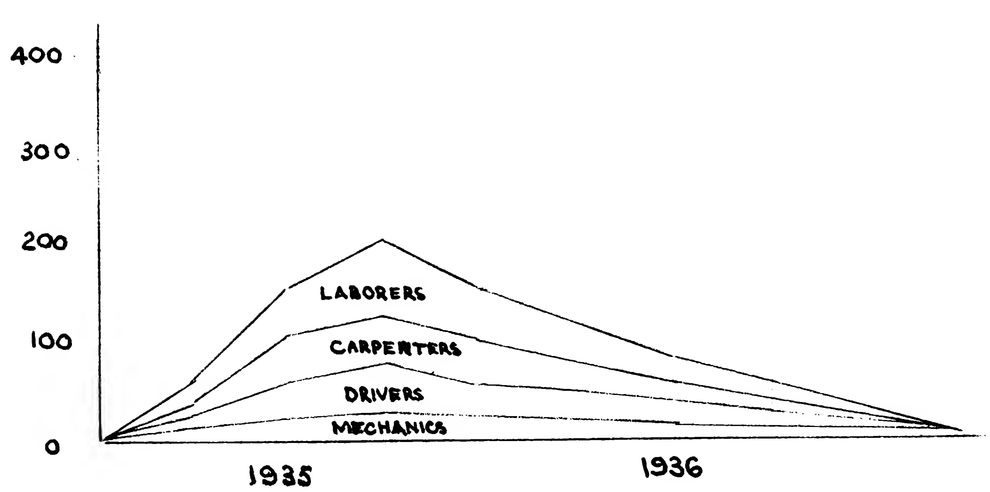


FIG 13 CUMULATIVE EMPLOYMENT SCHEDULE

RAW MATERIALS

The cost of raw materials is only a fraction of the total cost of major jobs, due chiefly to two reasons.

(a) The high cost of labor leading to the increase of mechanization and the corresponding increase of plant cost.

(b) Resulting from this increased mechanization the use of cheaper raw materials, even though in greater quantitiies has developed.

This is particularly noticeable in earth moving fields, resulting in earth dams, and road and railways using extensive cut and fill balance, instead of bridgework.

However, where raw material is used its cost is generally a reflection of the labor price. As the price of labor rises and falls; in economical cycles, so the material price varies. This is very well illustrated in the "Cost Indexes" as published in the"Engineering News Record" and similar American periodicals. These cost indexes are prepared on the basis of the costs in a particular base year, usually 1913, and their value and their variation give both the price and the trend.

Thus it should be possible to foresee periods or rising prices, and to buy sufficient material to avert this loss; but this is not possible for the following reasons:-

(a) While some materials, such as reinforcement do not need great care in storing, others such as cement do, and for the whole of the cement to be stored on the site for the whole period of the job would be unreasonable. The cost of the shelter would be disproportionate and the risk of deterioration too great.

(b) The capital outlay required to buy the whole of the raw material would probably be greater than the Contractors entire assets, and so it is usual to schedule the less economical buying in smaller quantities throughout the life of the job, as funds become available.

While on the subject of storage, it is well to note that the arrival of installed equipment on the site must also be scheduled. If a turbine arrives on the job before it is required it risks injury and must be adequarely housed. Against this it would be best to have an embeded turbine scroll on the job well ahead of its required time, as its absence could hold up the programmes of concrete pouring and so disrupt the whole job. As can be seen it is a matter of judgement and balance.

PLANT COST

This item is one of the most variable items, and because of the increasing emphasis on plant, any information regarding plant costs is of value. Such information can be obtained from records in the form of a Card System, with a card for each item of plant. This card can be used to record the initial cost, the cost of replacement parts and maintenance hours. The fuel lubricant waste etc., can be recorded on the operator's daily report form, and this information, together with the Property Card informationcan be used to gauge the rate of expenditure on the plant at any particular time.

PLANT - - - - NO. - - - - OPERATOR - - - - DATE - - - -

WHERE WORKING	WORK DONE		STORES DRAWN			
	DESCRIPTION	AMOUNT	FUEL OIL GALLS.	ENG. OIL GALLS	GREASE LBS	WASTE LBS

TOTAL HOURS WORKED - - - -

REMARKS. - - - - - - - - - - -

FIG. Plant Operators' Daily Report Form.

The importance of this recorded information can be realised when we examine the following problems:-

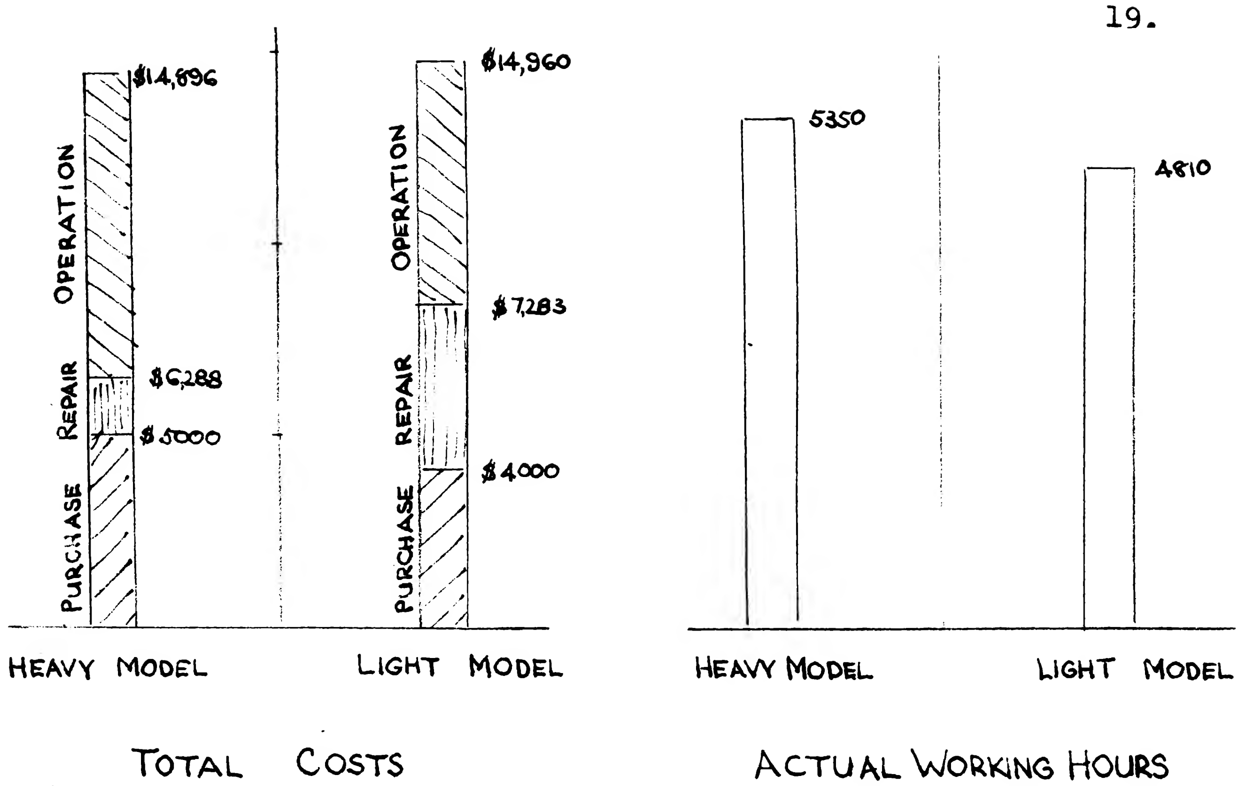
(a) To decide which of say 2 machines is the best for a job.

(b) When to buy new machines to replace older uneconomical ones.

(a) When choosing between a heavier and from the point of view of first cost, more expensive item, and a lighter cheaper item, e.g., between diesel and petrol driven units, the comparative costs over a period of twelve months spent on the same class of work would be shown in Fig.

It can be seen that although the heavier model costs more, due to less shut downs for maintenance, the hours worked are greater, and so the Unit Cost is lower. The heavier unit is the one which should be used.

(b) If, from the figures on records kept, we were to plot the hours worked against maintenance costs, we would get a diagram as shown in Fig.



COMPARATIVE UNIT COSTS

HEAVY MODEL $= \frac{14,896}{5350} = 2{\cdot}78$ \$ PER HOUR

LIGHT MODEL $= \frac{14,960}{4910} = 3{\cdot}11$ \$ PER. HOUR

FIG. Comparative Costs of Different Machines.
The cost of repairs is low at the start, but increases with time. However, due to the number of hours worked, the rate in cost per hour decreases to a minimum and for a while stays around this figure.

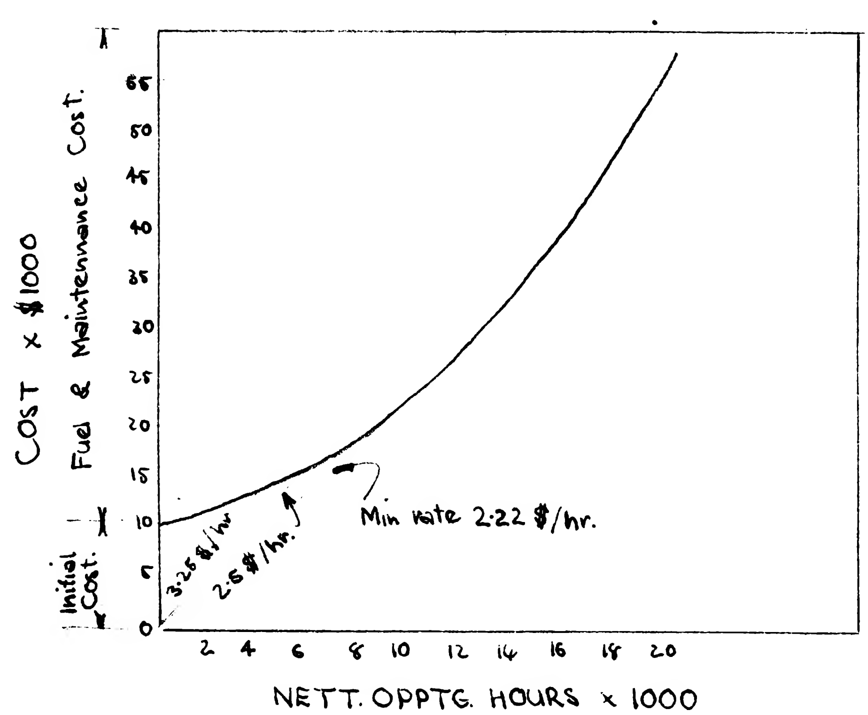


FIG. Graph of Performance Cost versus Life of Equipment.

As maintenance costs increase and time off for repair becomes more frequent, the unit rate starts to increase, and the operating of the machine becomes uneconomical. At this stage the machine should be sold or scrapped, and replaced with a new, more efficient machine.

Due to lack of funds, or the job nearing completion, it may be decided however, to keep working these machines, even though at a theoretical uneconomical rate.

This form of diagram can also be used to decide between buying a new machine and buying the same machine second hand.

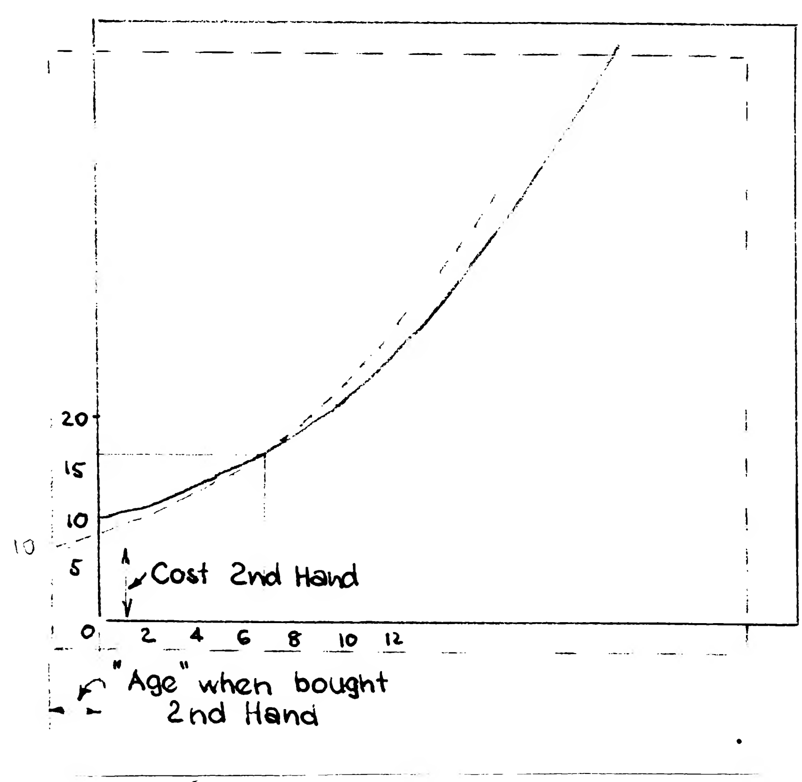


FIG. Comparative Costs of different machines
Choosing between new and second hand plant.

The double diagram, overlapping as shown, gives the story that after a certain time the unit rate of the new machine catches up with that of the old machine, and for jobs totalling more hours than at point A. it is more economical to buy new equipment.

CONTINGENCIES

With all large projects there are items which, although not large, are not negligable, and which cannot be costed under "On Cost" because they would give a false impression of that item. They are related to the actual job and must be costed under "Direct Cost", i.e., miscellaneous costs cannot be lumped in with "On Cost", which has a definite function.

ON COST

"On Cost" varies with the size and importance of the job, and also with the nature of the job, e.g., for a "Ribbon" developement, such as canals, roads, railways etc., it would be necessary to set up small camps at the centres of operation. In the case of "Cluster" type jobs, such as dams, power stations, etc., it is

better to locate the entire camp adjacent to the job.

"On Cost" can be broken in to two divisions.

(1) Cost of transfer of organisation to site, establishment of camp and depot, and their maintenance.

It was once the practice to estimate this item on the basis of £50 per man, with quarters being a bunk house, a mess hall and a store, buildings being built as simply as possible to last the life of the job only, but now the cost of £100 per man is not excessive, and the theory is that if a man's efficiency can be increased by 5% by providing better quarters, the investment is worth while. In hard cash, if a man works for a period of three years on a project, he will have earned

3 X 50 X £20 = £3,000.

of which 5% equals £150, which almost pays for the extra amenities. Again the higher class of construction means that the buildings will have a much longer life, maintenance will be lower, and they will be able to dismantle them and use them on another job; or else they may be used as permanent staff quarters when the job is handed over to the owners.

Other items, which should be regarded as worth while investments, are efficient first aid post, a shop, and possibly a hall. For the larger jobs, would be added a hospital, a cafeteria and a cinema. This is especially possible if an agreement can be made between~~can be made between~~ contractor and principal, to help defray the expenses, by having these items included as permanent site buildings,and including them as "Bid" items when tendering.

Under the heading of setting up camp, are included such items as electric light and power, in the form of a line to the site and a transformer installed, water supply to both the camp and the job, seqage and garbage disposal, and telephone, at least to the Engineer's Office.

(2) Items relating to the wages, which are estimated on the basis of percentages are:-

(1)	Workers' Compensation Insurance	= 2.5%	
(2)	Pay Roll Tax	= 2.5%	of gross wages
(3)	Annual Holidays Statutory Holidays Short & Long Service Leave Sick Leave	= 13%	
(3)	Engineering & clerical Administrative costs for staff directly engaged on job	= 10% of direct labor cost	

This totals 28% of Direct Labor Cost, and as Labor Cost is approximately 40-50% of the total cost, "On Cost" represents approximately 10% of the total cost.

This last item may seem excessive, especially on large jobs, where 10% of total cost may approach £1,000,000, but from records this has been found to be around the average.

Item 2 above is unavoidable, since it is set by Court and and Union Decisions.

Item 3 can hardly be reduced, and considered as an investment of 10% to ensure that the remaining 90% of the labor cost receives its full value, it is more profitable than spending 5% to ensure that 95% is used at only 80% efficiency, due to lack of supervision.

SUMMARY OF COST

Once we know the factors which cause the costs, and the way in which these factors vary, i.e., once the job has been programmed; then we can programme the costs. This is done in a similar manner to the job programming, item by item, and like the job programme the items can be collected and charted to give an accumulative total at any time.

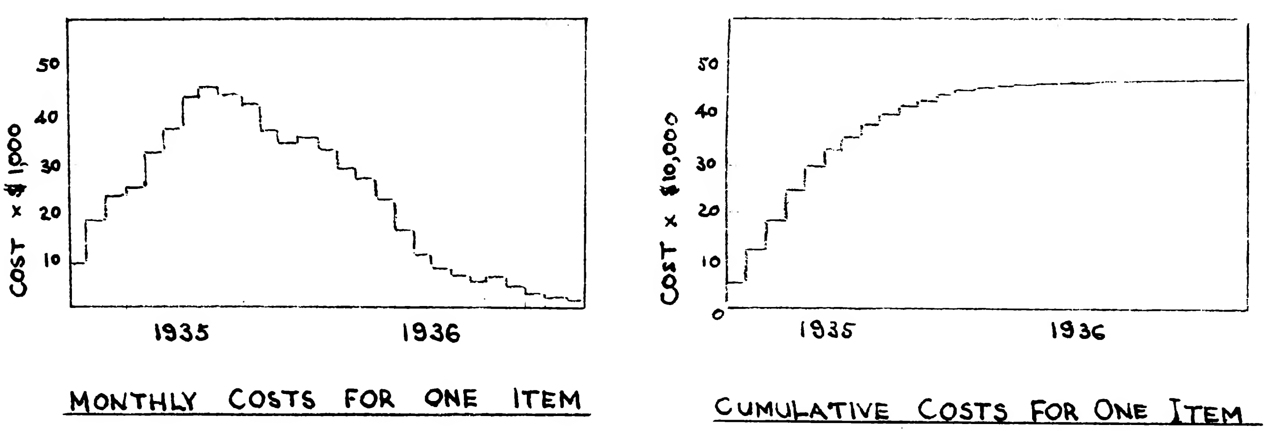


FIG. Costs for Individual Items.

From the various records of costs incurred throughout the job, the accumulative total can be compared with the amount forecast, and steps taken accordingly. If the accumulated cost is less than the forecast, then the job is going well, and the Contractor knows that he has an opportunity to make extra profits. If, however, the accumulated costs are more than the scheduleud costs, then the Contractor knows that the job is not being done economically. He will generally find that the extra is being eaten up by his plant, either by not working at the most economical speed,or not in the best manner; or else it is beyond its economical life. These faults can be determined by carrying out time and motion studies, taking tests on the plant using dynamometers and other recording equipment; and also by consulting his records in the manner mentioned previously.

If the job is being done under Day Labor, and is assumed as being carried out in the most economical manner, then the estimate is assumed as being unreal. A fresh estimate should be carried

out to determine the money required, over and above the original estimate to complete the job. This money is then granted, and the job completed. If the money is not available however, the design must be modified, and economies made; e.g., a gravel road may go without a bitumen top until more money becomes available or else such economies are affected that the cost to completion comes within the budget.

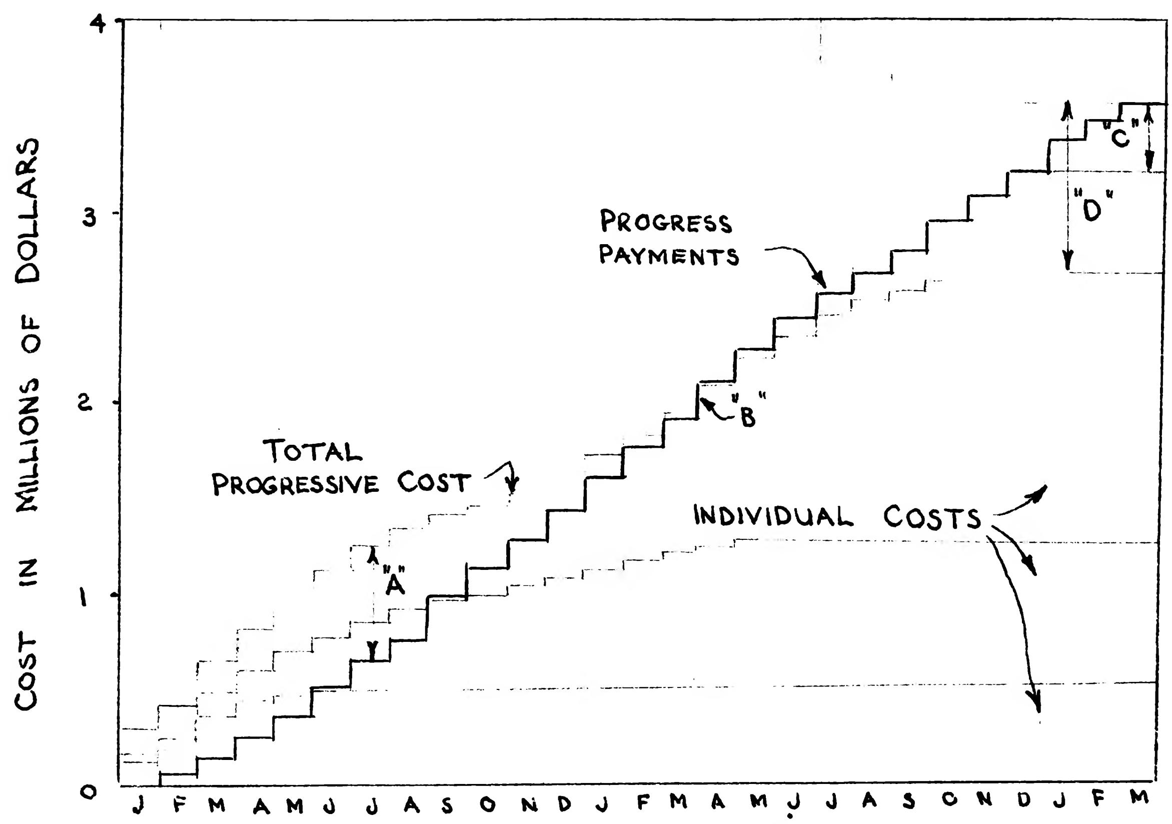


FIG. Progressive Financial Schedule for Whole Project.

A = Maximum amount by which job becomes "in debt" and which may require to be covered by a Loan.

B. Point at which payments coming in balance costs going out: here, after the job has been in progress for fifteen months.

C. Payment of Retained Percentage

D. Total Profit on Job.

CONCLUSIONS

A. PROGRAMMING.

1. Providing the Planning Staff know enough about the job, the site, the plant position, the labor position, and the money available; the programme reduces itself to a series of quantities to be performed betweem given time limits, being in the Programmer's opinion the best and most economical way of doing the job.

The Engineer in Charge of the job, should realise this and delegate his authority to deal with details, while he concentrates on the over all picture, in terms of these quantities and time limits.

2. Providing the due importance has been paid to the relative sections of the job, when it is in the programming stage, then the job becomes simply a matter of maintaining a series of set rates of production. This in turn reduces to a matter of keeping a number of machines working at a given rate for a given number of hours a day, week after week.

This question of keeping the machines working involves a realisation that two of the major plant cost items are in replacement parts, and time lost due to outages. Thus it is better in the long run to set up a maintenance and overhaul schedule, and to stick to it religiously.

3. Since nothing clarifies an idea as much as a diagram, the programmes should be chrystallised in the form of a series of charts, preferably simple, in different colours, or in some way to make them stand out and force home their meaning.

4. Similarly, nothing gives a better idea of whether the job is headed for success than a comparison of progress with programme. Therefore, the charts should be designed to allow progress to be marked on them, and should be marked up regularly and hung in a prominent place. This enables someone else, other than the Engineer in Charge, to understand the position, and encourages interest in the job.

5. Essential information needed in performance figures, which enable comparative estimates to be carried out to decide on the relative merits of different schemes. Thus production records in the form of Individual Cards for each major machine should keep a tally of hours of service, replacement parts, and periods spent in maintenance. They can be kept with other records of the job and used in planning future jobs of a similar nature.

B. COSTS

1. When all the items likely to incur costs are known, then a complete picture of the financial structure can be developed; not only how much, but when the cost will be incurred.

2. The preliminary cost to start a job, i.e., money invested before a progress payment is made, may be large, but it should be remembered that the job is usually scheduled for greatest production in second or later years, and it may be this long before the payments received catch up with costs going out. Again, the initial cost may not be the greatest amount to which the job becomes "in debt", in which case it may be necessary to raise a loan to cover this period of insolvency. The interest on this loan must also be taken in to account.

For a job of any magnatitude, the possibility of buying new and more economical equipment for this job, which will mean a bigger profit and probably pay for itself in to the bargain, as against using existing equipment, should always be investigated. The spending of so much money before a job is started is a prospect that would try the courage of most Australian Contractors; but it seems to be the standard practice in America, and the juggling of Bonds and Loans and interest to cover this initial cost just part of contracting.

3. When the job ~~is~~ in progress, in order that a sound financial position may be maintained, efficient cost indexing and clear records of material received, wages paid, hours worked, accounts met etc., should be kept; and these used to regularly compare estimated with actual cost.

4. As in programming, these records can be invaluable in planning the cost structure of future jobs, especially if used to keep a system of up to date "cost indexes".

BIBLIOGRAPHY

1. Book "Construction Planning & Plant"
by A. J. Ackerman & C.H. Locker

2. Book "Construction Estimating & Costs"
by H. E. Pulver

3. Journal "Planning Engineering Construction"
by G. B. Towers - Commonwealth Engineer - October 1950

4. Journal "Cost Estimates for Road Construction"
- Main Roads - June 1949

5. Journal "Construction Cost Control Shows Efficiency of Man & Machine"
by M. H. Maxton - Civil Engineering - January 1949

6. Journal "Construction Cost Control Simplified"
- Engineering News Record - May 1948

7. Hand Book "Principles of Modern Excavating & Earth Moving Equipment."
by K. F. Park (For Le Tourneau Co., Ltd.)

8. Brochure "Procedure to be adopted in connection with estimating & Costing Construction Works"
by P. W. D. N.SW. For use of its Officers. June 1946

9. Journal "Scheduling Production and Recording Contract Costs"
by - Nat. Assoc. of Cost Accountants
Feb. 1950.

10. Journal "Method of Costing Civil Engineering Works"
by H. C. Butler - Concrete & Construction Engr.
May, 1946